Fully-Implicit High-Order Sharp-Interface (SI) Method for Multi-Material Contacts in All-Speed Fluid Dynamics

R. Nourgaliev, P. Greene and B. Weston

Lawrence Livermore National Laboratory, Design Physics Division
P.O. Box 808, L-170, Livermore, CA 94551, USA
e-mail: nourgaliev1@llnl.gov

ABSTRACT

Accurate and robust capturing of interfacial discontinuities in coupled simulations of multimaterial fluid dynamics and solid mechanics remains a challenging numerical problem [1]. This is especially crucial when the underlying numerical schemes are high- (more than the 2^{nd}-) order accurate. In the present study, we describe a new numerical algorithm that enables robust simulations under large discontinuities in material properties across interfaces, without numerical smearing and associated loss in accuracy. The method is based on the reconstructed Discontinuous Galerkin (rDG) formulation, combined with the fully-implicit time discretizations and solved with a Newton-Krylov (NK) algorithm [2]. The main driving concept is to avoid explicit differentiation across material discontinuities, using material-sided least squares reconstruction and interfacial jump conditions to maintain sharp multimaterial contact discontinuities. The method is designed to work with both the immersed interfaces ("mix"-cells) and across the dissimilar-material element faces ("pure"-"pure" cells). The concept of attaining a sharp solution (jump-condition-guided reconstruction) is the same in both cases. The difference is in that the immersed-interface version is a two-step process, i.e. (1) constructing the level set cutting the "mix" cells into curvilinear integration subcells, and (2) reconstructing multiple solution fields (one for each material) in these cells, which can be utilized to assemble (integrating conservatively) the residuals for the conservation laws evolved in the NK-based iterative solution procedure. The "pure"-"pure" element face version reconstructs the solutions on each side of the face, which are then used directly at the face flux integration stage. We will discuss similarities and differences of our SI method compared to the well-known Ghost Fluid Method (GFM) in finite-volume formulation of multi-fluid flows, and the xFEM methodology for dealing with cracks in structural mechanics. In the present work, we demonstrate the performance of this SI reconstruction for laser applications, which are important for both advanced manufacturing and defense related analyses.

REFERENCES

[1] R. Nourgaliev, M.-S. Liou, and T. G. Theofanous, "Numerical prediction of interfacial instability: Sharp Interface Method (SIM)," *Journal of Computational Physics*, **227**, pp. 3940–3970, 2008.

[2] R.Nourgaliev, H.Luo, B.Weston, A.Anderson, S.Schofield, T.Dunn, and J.-P.Delplanque, "Fully-Implicit Orthogonal Reconstructed Discontinuous Galerkin for Fluid Dynamics with Phase Change", *Journal of Computational Physics*, **305**, pp.964-006, 2016.

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344, and funded by the Laboratory Directed Research and Development Program at LLNL under project tracking code 19-ERD-015.